BRL

TECHNICAL NOTE NO. 1452
MARCH 1962

PRESSURE PROFILES OF DETONATING BARATOL MEASURED WITH SULPHUR GAUGES

G. E. Hauver
P. H. Netherwood

Department of the Army Project No. 503-04-002
Ordnance Management Structure Code No. 5010.11.815

BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

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A B E R D E E N   P R O V I N G   G R O U N D,   M A R Y L A N D

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GEHauver/PHNetherwood/bjw
Aberdeen Proving Ground, Md.
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ABSTRACT

The dependence of the electrical conductivity of sulphur upon pressure is used to measure a pressure-time profile for detonating Baratol. The measurements indicate an initial pressure spike and tend to further confirm the hydrodynamic theory of detonation proposed by von Neumann. Preparation of sulphur gauges, method of calibration and preliminary performance tests are described.

I. INTRODUCTION

Alder and Christian[1], in 1956, reported a large increase in the electrical conductivity of some ionic and molecular crystals when these materials were subjected to transient pressure in the order of 250 kilobars. They proposed that the materials undergo a transition to the metallic state. Joigneau and Thouvenin[2], in 1958, reported a large increase in the electrical conductivity of sulphur when it is subjected to high transient pressure, but detected no sudden or discontinuous transition to metallic conduction. The experimental arrangement for their investigation is shown in Figure 1. From their results, it was inferred that a modified system might permit sulphur to be used as the active element of a pressure gauge for measurements in the hundred-kilobar range.

II. PREPARATION OF A SULPHUR GAUGE

Figure 2 shows the sulphur gauge used for this investigation. The main body of the gauge is made of Teflon, which was selected because it is non-polar and does not generate spurious signals when shocked[3,4], does not conduct at pressures below several hundred kilobars and is a close match to the shock impedance of sulphur. The gauge is prepared by machining a shallow cavity in the Teflon base. The Teflon is drilled and copper electrodes are pressed into place, as shown in Figure 2. Gold foil, 0.001-inch thick, connects the copper electrodes to the cavity region where the sulphur is placed. Vacuum melted sulphur is cast into the cavity and, after solidifying, the excess is ground away, leaving a thin layer of sulphur 0.007-inch thick to bridge the gap between the gold foils. The 0.007-inch sulphur thickness permits adequate time resolution for most measurements. Teflon front insulation, usually 0.010-inch thick, is bonded to the surface with an epoxy matched to the density of Teflon by the addition of inert filler. A 0.010-inch Teflon front permits the sulphur to be close to the point where the measurement is desired and minimizes attenuation.

III. CALIBRATION

Figure 3 shows the experimental arrangement used for calibration. A plane detonation wave impacts an aluminum plate maintained at ground potential. The plate thickness controls the pressure to which the sulphur is subjected. A representative conductance-time signal for the shocked sulphur is shown in Figure 4. The maximum sulphur conductance (minimum resistance) is related to the shock front pressure. Figure 5 shows the sulphur calibration curve, plotted as resistivity vs pressure.

Appropriate RC circuits are used for the measurements. They consist of a known resistor in series with the sulphur. A known voltage is maintained across the combination, and potential drop across the resistor is recorded with an oscilloscope.

IV. PLATE IMPACT TESTS

Response of the sulphur gauge to a transient pressure pulse was tested by plate impact, because existing theory[5] predicts the basic pressure profile features. Figure 6 is a schematic diagram of the experimental arrangement. A 24ST aluminum plate is driven by an explosive to produce plane impact on a 24ST aluminum target in contact with the sulphur gauge. Driver plate thicknesses were 0.062 inch and 0.125 inch, and target plate thickness was varied.

Figure 7 shows the pressure-time profiles and the oscilloscope conductance-time records from which they were obtained. For both 0.062-inch and 0.125-inch driver plates, flat-topped pressure-time curves were obtained with a 0.062-inch target over the sulphur gauge. Small variations in pressure along the top are attributed to impedance mismatch present in the gauge system. As the target thickness is increased, the pressure-time pulse is reduced to a triangular shape. The peak pressure of the spike is reduced by further increase in target thickness.

The flat-topped pulses are not as wide as predicted by theory if the hydrodynamic sound velocity is used. Also, the pulse is reduced to a triangular shape sooner than expected. These observations tend to be supported by a recent paper of Morland[6] who predicts that a velocity higher than the hydrodynamic sound velocity might be associated with the initial pressure relief.

The plate impact tests show two features about the response of the sulphur gauge. First, the gauge continues to respond to pressure, at least a constant pressure, after the initial pressure rise corresponding to the shock front. Second, it indicates a rapid pressure decrease when the rarefaction arrives, with no evidence of a long "conductance tail". From these two features it has tentatively been assumed that the sulphur gauge is responding to pressure-time profiles.

V. PROFILE MEASUREMENTS WITH DETONATING EXPLOSIVE

Tests were performed in which a sulphur gauge was placed against the end of an explosive cylinder. The explosive selected was 67/33 Baratol because the present sulphur gauge does not enable measurement of pressures as high as those encountered with more energetic explosives. At pressures encountered with more energetic explosives, the sulphur resistance becomes too low to measure accurately by the techniques presently used.

Figure 8 shows the oscillograph conductance-time record used to determine the pressure-time curve shown in Figure 9. The values of pressure are those at the interface measured with the sulphur gauge. The curve is interpreted to show the reaction zone (von Neumann spike) followed by the Taylor rarefaction. The intersection of the two portions of the curve corresponds to the Chapman-Jouguet pressure which is calculated to be 156 kilobars, using the interface equation,

$$P_x = P_s \frac{(\rho_x D_x + \rho_s D_s)}{2 \rho_s D_s} .$$

In this equation, P, ρ and D are pressure, density and shock (detonation) velocity, respectively. Subscripts x and s refer to the explosive and sulphur, respectively. Rise time limitations of the conductance circuit do not permit a determination of the maximum spike pressure. The spike width is 0.3 microsecond, indicating a reaction zone length in the order of 1.5 millimeters.

VI. DISCUSSION

The pressure-time measurements with the sulphur gauge in contact with detonating Baratol give evidence of an initial pressure spike, and lend additional confirmation to the theory of detonation by von Neumann and others.

While this degree of success has been achieved, possible shortcomings should be pointed out. First, the influence of temperature on conductivity has been neglected, in that the compression-temperature relationships associated with the shock jumps used for calibration have been assumed to be the same as the compression-temperature relationships existing under conditions of the pressure profile measurements. Second, although compressed sulphur is assumed to be an intrinsic semiconductor, impurities may influence the conductivity and could introduce reproducibility problems. Both of these points must be considered in further investigation.

G. E. Hauver

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P H Netherwood

P. H. NETHERWOOD

VII. REFERENCES

1. B. J. Alder and R. H. Christian. Metallic Transition in Ionic and Molecular Crystals. Phys. Rev. 104, 550-1, 15 Oct. 1956.
2. S. Joigneau and J. Thouvenin. Electrical Conductivity of Sulphur Under the Action of a Shock Wave. C. R. ACAD. Sc. (Paris) 246, 3422-5, 23 June 1958.
3. R. J. Eichelberger, Effect of Very Intense Stress Waves in Solids. International Symposium on Stress Wave Propagation in Materials, Interscience Publishers. Inc., New York, 1960.
4. G. E. Hauver, BRL Technical Note No. 1356, APG, Md. October 1960.
5. G. R. Fowles, Journal of Applied Physics 31, 656-61, April 1960.
6. L. W. Morland, Phil. Trans. Royal Soc. London A251, 341-383, 11 June 1959.

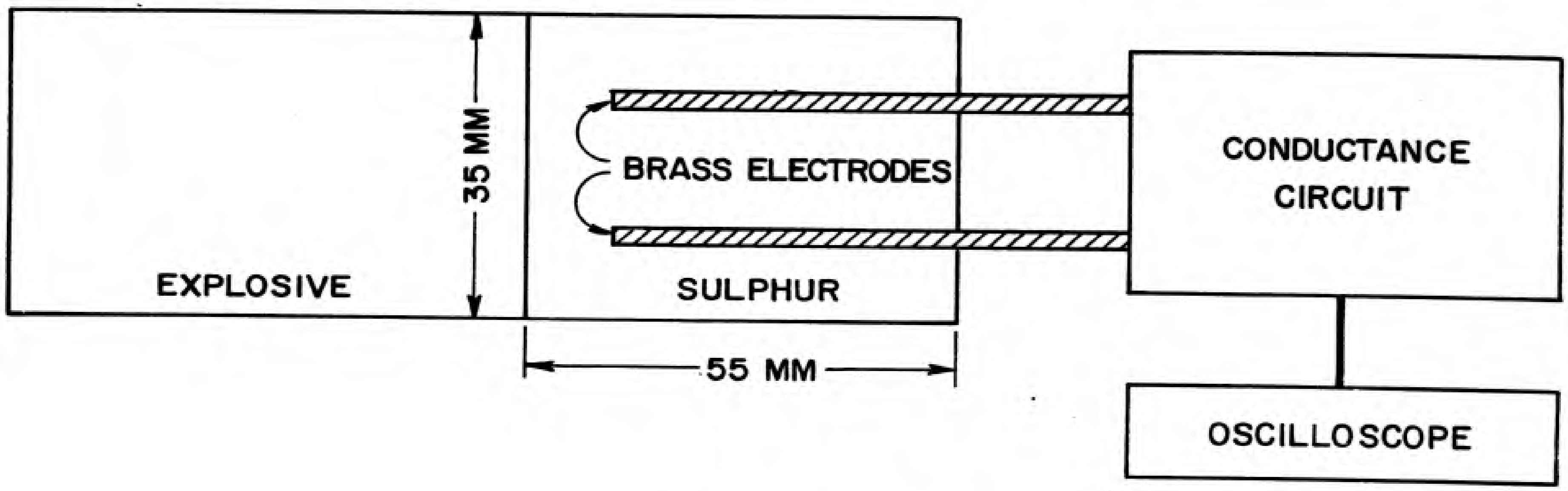


FIG. I
EXPERIMENTAL ARRANGEMENT USED BY JOIGNEAU AND THOUVENIN

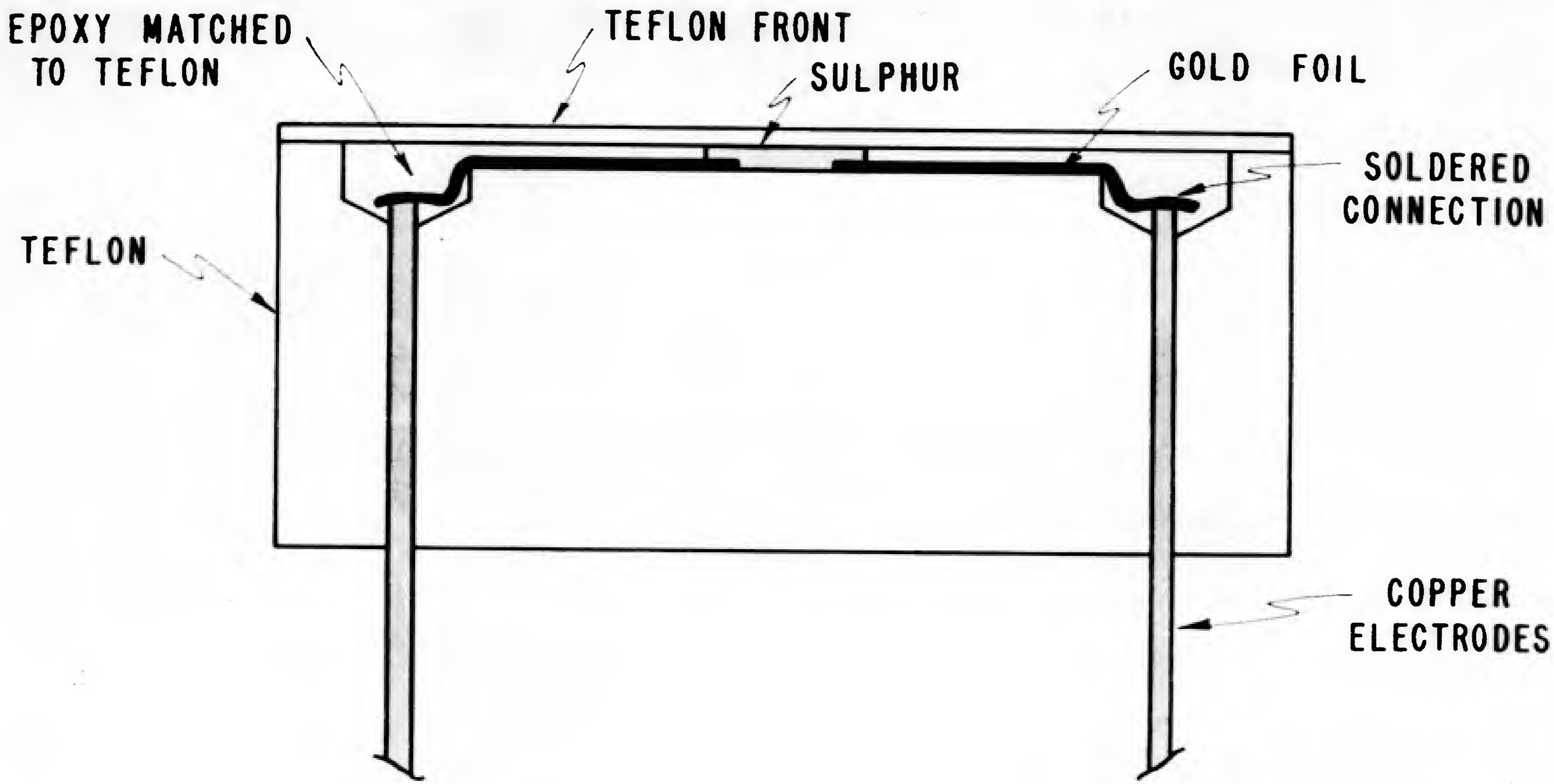


FIGURE 2 – SULPHUR GAUGE

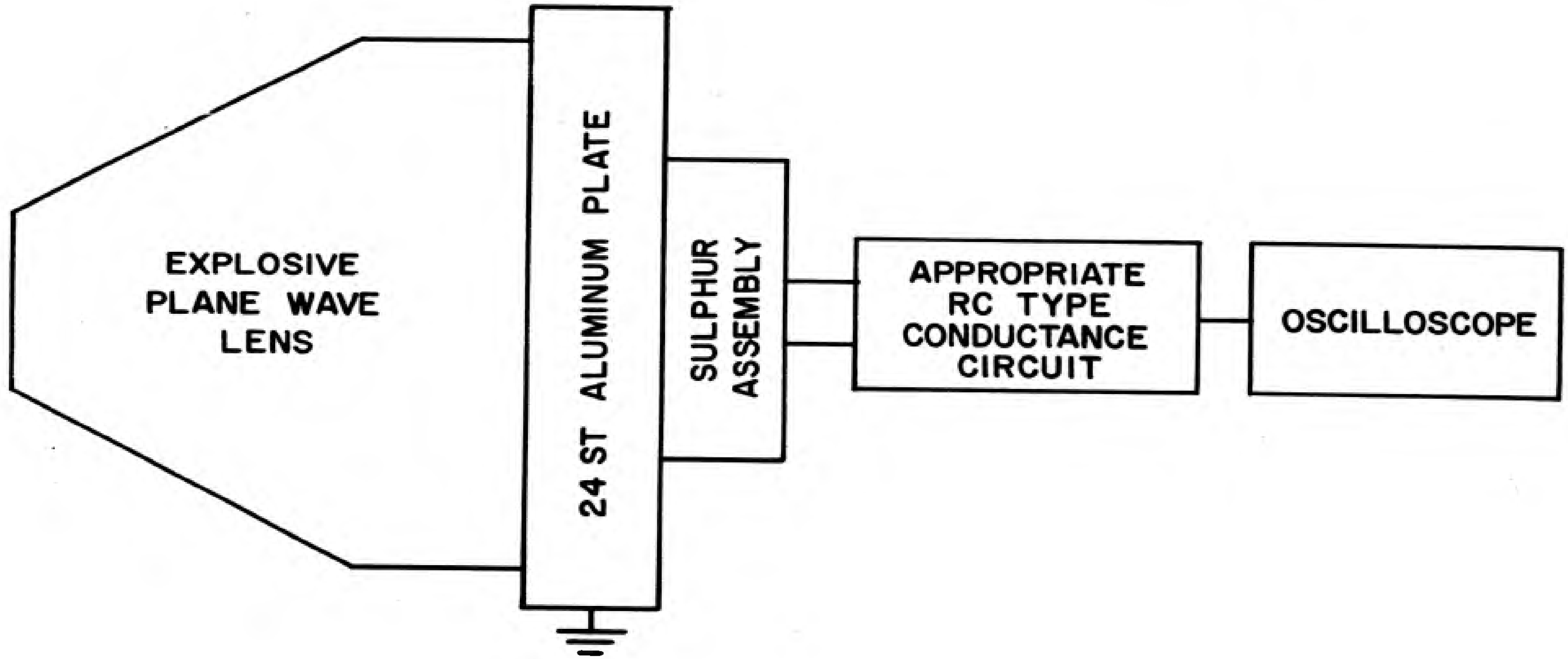


FIG. 3
SET-UP USED FOR CALIBRATION

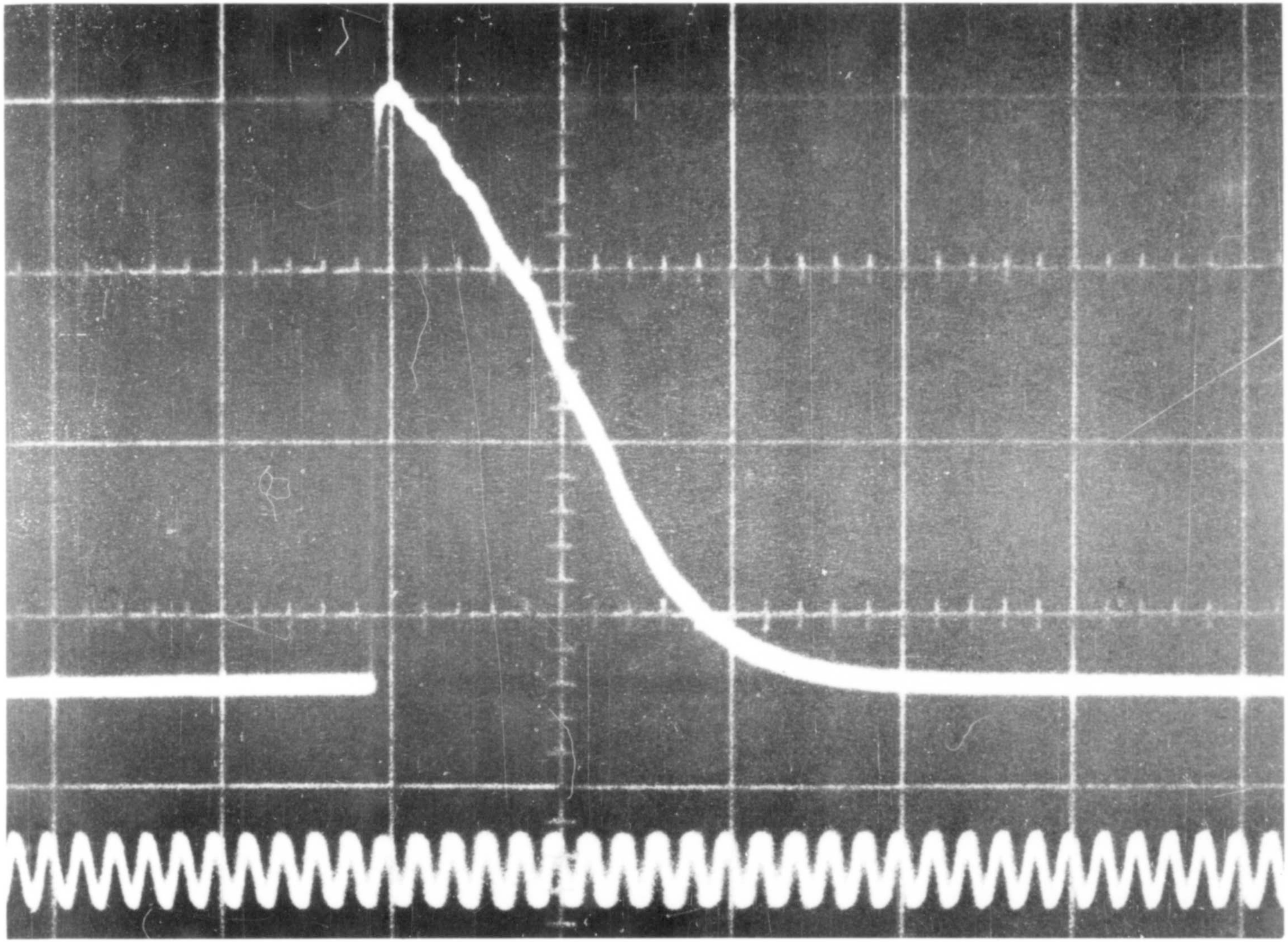


FIGURE 4
OSCILLOGRAPH CONDUCTANCE - TIME RECORD

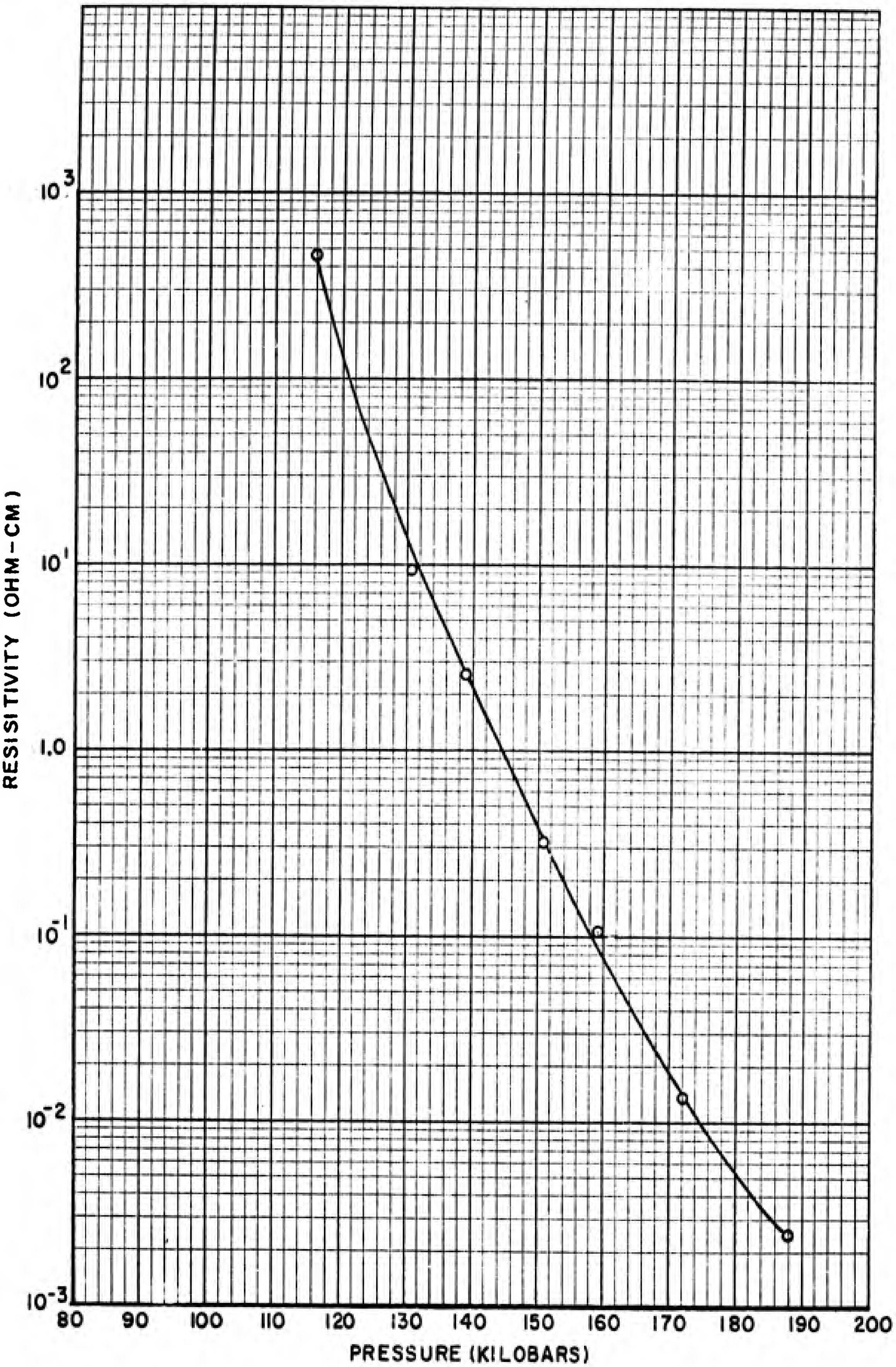


FIG. 5-SULPHUR CALIBRATION CURVE

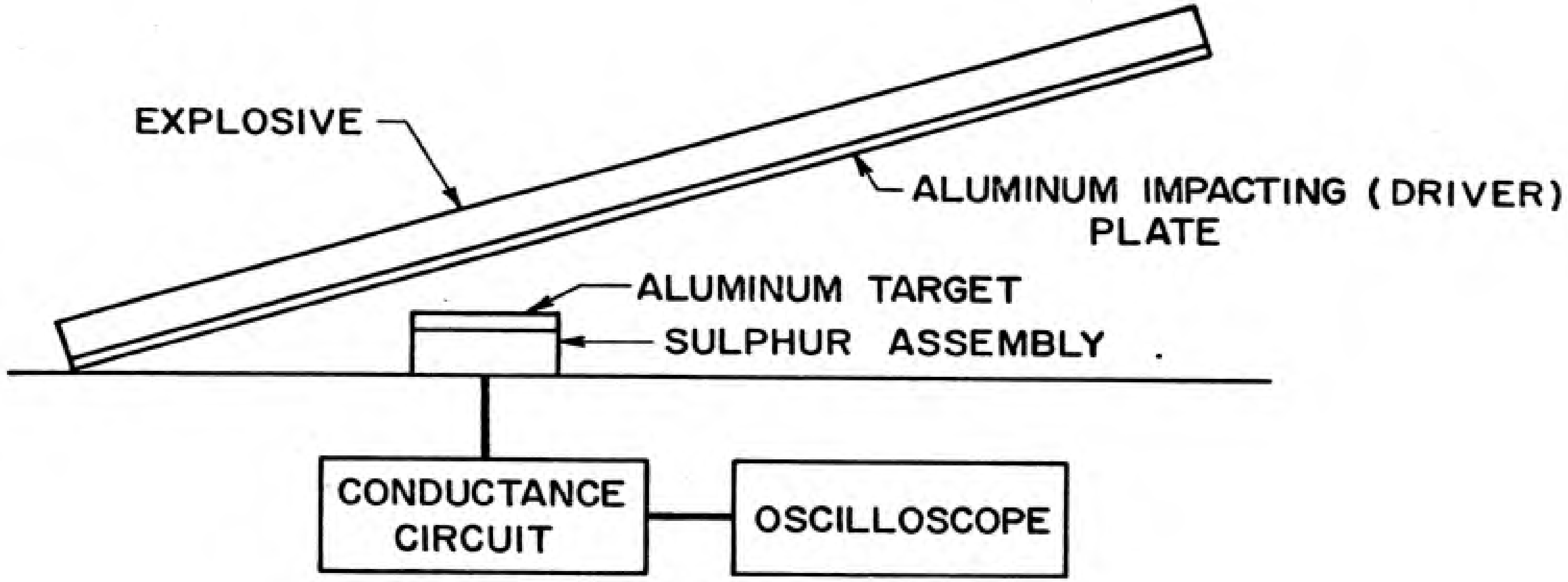


FIG. 6
EXPERIMENTAL ARRANGEMENT USED FOR PLATE IMPACT TESTS

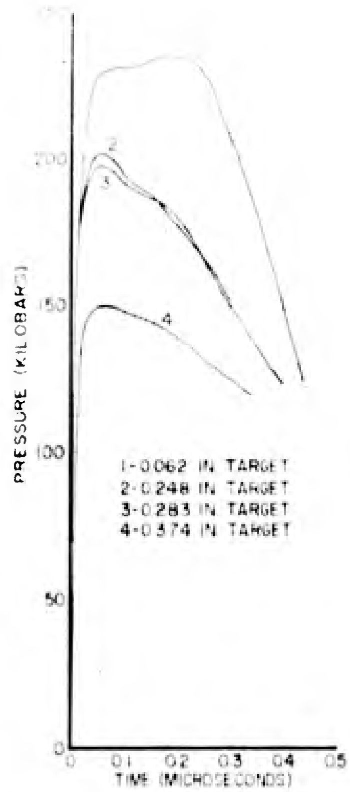


PLATE IMPACT PRESSURE PROFILES (0.062 IN. PLATE)

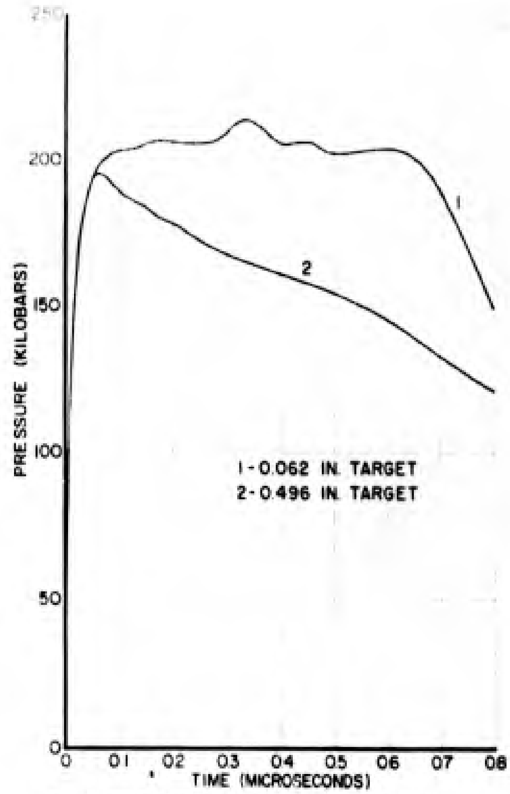
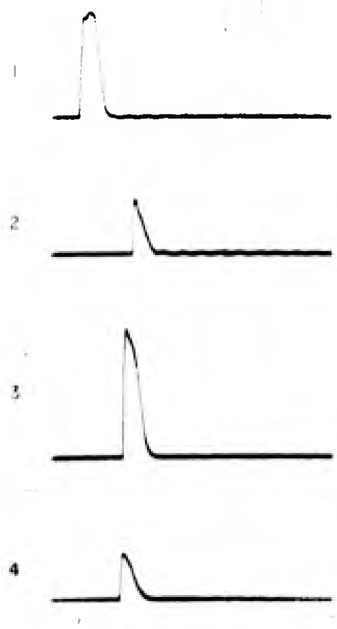
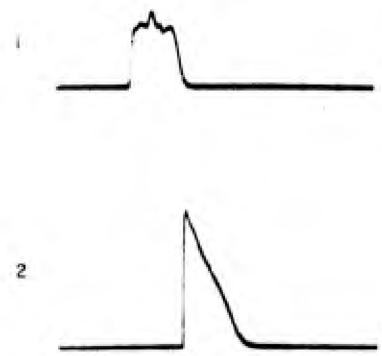


PLATE IMPACT PRESSURE PROFILES (0.125 IN. PLATE)



OSCILLOGRAPH CONDUCTANCE - TIME RECORDS
FOR 0.062 INCH PLATE IMPACT



OSCILLOGRAPH CONDUCTANCE - TIME RECORDS
FOR 0.125 INCH PLATE IMPACT

FIGURE 7
PLATE IMPACT TESTS

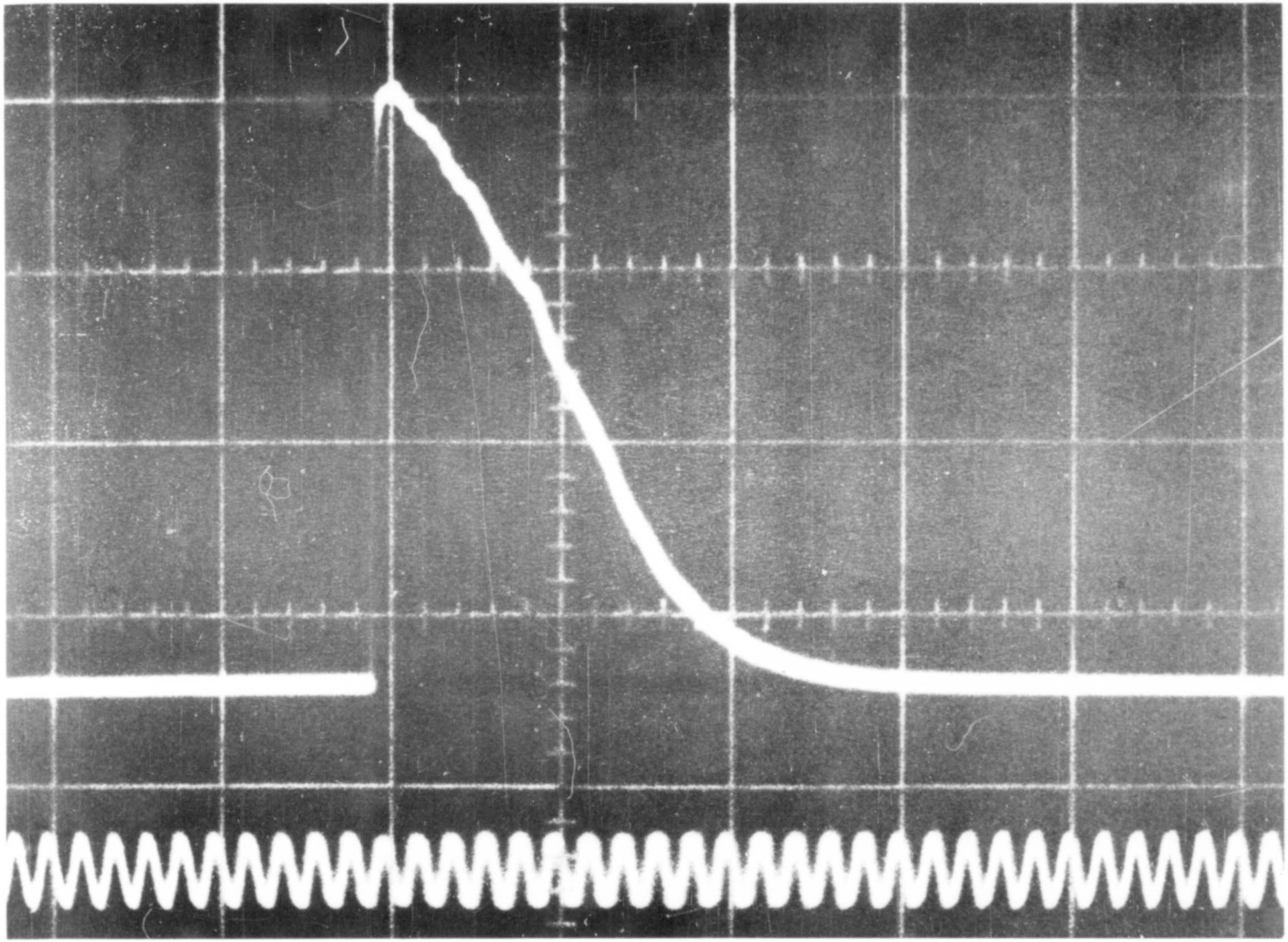


FIGURE 4

OSCILLOGRAPH CONDUCTANCE - TIME RECORD

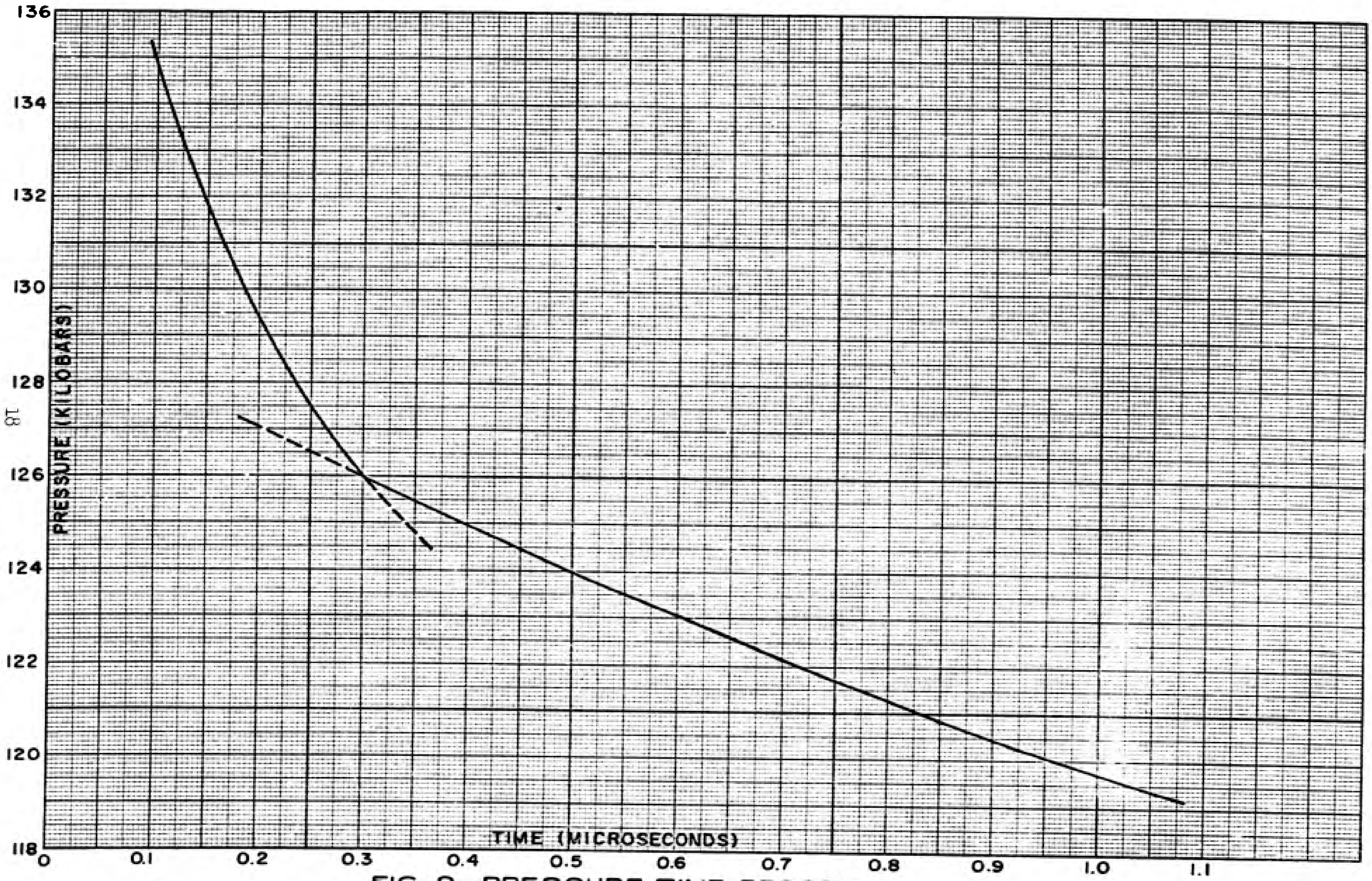


FIG. 9 – PRESSURE-TIME RECORD

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G. E. Hauver and P. H. Netherwood

Pressure gages - Design
Blast effects - Measurements

BRL Technical Note No. 1452 March 1962

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UNCLASSIFIED Report

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